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Fisheries in southern Brazil: a comparison of their management and sustainability

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Summary

Defined as operational units, the estuarine and marine fishing production systems (FPS) from the two southernmost states of Brazil, Santa Catarina and Rio Grande do Sul were analyzed using the RAPFISH technique with respect to sustainability of fisheries. The FPS were defined by 49 attributes divided into five fields: economic, social, ecological, technological and managerial. Data were obtained from the literature and interviews with fishers, skippers, and ship owners in 2003 and 2004. Overall, 26 FPS were identified: nine small-scale; three medium-scale; ten large-scale operating on the shelf, upper slope or nearby oceanic waters; and four large-scale fishing systems on the upper slope or neighboring oceanic waters. The latter included only foreign vessels, which produced frozen products exclusively for export. Analyses of 15 selected attributes more closely associated with sustainability in the five fields of evaluation showed all FPS in an intermediate position between the extremes of ideal and bad, reinforcing the perception that no FPS in southern Brazil can be considered truly sustainable; evidence of clearly unsustainable FPS was also not found. Thus RAPFISH fell short of producing a clear pattern that could result in sound management, probably due to disagreement among the different dimensions of sustainability. All five fields of evaluation were equally weighted; however, it could be argued that the biological and ecological status of fisheries were not given enough emphasis in relation to the other dimensions. Dissimilarities within FPS and differences regarding sustainability levels must all be taken into consideration for sound management measures.

Introduction

Santa Catarina (SC) and Rio Grande do Sul (RS), the southern-most states of Brazil, stretch over 1183 km of coastline, with a wide coastal shelf and relatively high productivity (Gaeta and Brandini, 2006). Total marine fish landings recorded in both states reached 150 000 tonnes (t) in 2004 (IBAMA, 2005), 85% of which were landed by an industrial fleet composed of more than 700 boats over 20 t gross weight (Perez et al., 2001); the remainder were small-scale and middle-scale fisheries (i.e. artisanal fisheries) with more than 8000 boats (SEAP / IBAMA / PROZEE, 2005). Small-scale fisheries in SC tend to be more developed than in RS because the coast offers a larger number of natural ports; the coastline in RS is a continuous sandy beach with few landing sites for fishers. The total number of fishers in both states ranges from 15 000 to 54 000, depending on the source (IBGE, 2000; Haimovici et al., 2006a; Sunyé and Morisson, 2006). Following global trends, most fishing resources in southern and southeastern Brazil (22°–34°40′S) are overfished to the point where decreases in catch of some fish stocks make commercial fishing impossible (Haimovici et al., 2006b; FAO, 2007).

Ensuring the conservation of fisheries in SC and RS requires detailed understanding of their complex interactions. The main aim of this study was to identify and compare diverse marine and estuarine fishing systems and assess their sustainability on the coasts of RS and SC through a multidimensional perspective by considering several ecological, economic, technological, social and management attributes (Berkes, 2003). This study was part of a larger, nationwide project, 'RECOS', to assess use and appropriation of coastal resources in Brazil (Isaac et al., 2006).

Material and methods

A non-metric multi-dimensional scale (MDS) (Clarke, 1993) was used for different fishing production systems (FPS) to analyze their relative sustainability, following the Rapid Appraisal of Fisheries (Rapfish) methodology proposed by Pitcher and Preikshot (2001).

The fisheries in SC and RS were classified into homogeneous units entitled fishing production systems (FPS), based on field observations and peer-reviewed and gray literature (Haimovici et al., 2006a; Sunyé and Morisson, 2006). The FPS were defined according to the criteria: (i) fishing fleet (artisanal and industrial), (ii) fishing gear or method, (iii) target resources, (iv) environmental characteristics of the fishing grounds, (v) distance from fishers' residences to the fishing grounds, (vi) working relationships, (vii) fishers' income, and (viii) living standards and access to public services. Small-scale FPS typically use boats under 12 m, have few fishers, trips last one day, fishing areas are close to home, and incomes are low and informally divided. Mid-scale FPS use 9–20 m boats, trips last several days, fish are stored on ice, crew members are usually fewer than six, and income is low to medium and divided into shares. Industrial national FPS use 20–35 m boats, usually have 7–15 crew members, fish are stored on ice, trips last up to two weeks, and incomes are medium to high and suffice to ensure minimum wages to the fishers. Leased foreign fleet FPS use 25–60 m boats, have freezing and processing capacity, trips can last more than 30 days (Perez et al., 2003), crew members are more than 20, and foreign officers and the Brazilian deck crew earn the highest salaries (Table 1).

For each FPS, 57 attributes were initially defined for all Brazilian fisheries. After some considerations regarding south-

Table 1
Main characteristics of the estuarine and marine fishing production systems (FPS) from the Brazilian states of Rio Grande do Sul and Santa Catarina

1	ARC – Small-scale fishery using 5–8 m open-deck boats mainly in Patos Lagoon, but also in coastal waters. Stationary nets, bottom trawl and gillnets targeting shrimp, croaker and mullet
2	ARE – Small-scale fishery using 5–8 m open-deck boats. Exclusively in Patos Lagoon estuary. Stationary nets and gillnets targeting shrimp, crab and silversides
3	ARL – Small-scale fishery using 8–12 m open-deck boats mainly in Patos Lagoon estuary, but also in fresh waters. Bottom trawl and gillnets targeting croaker, mullet and catfish, and freshwater species
4	ARM – Small-scale fishery using 8–12 m open-deck boats mainly in coastal waters, but also in the estuary. Bottom trawl and gillnets targeting shrimp, croaker and mullet
5	ARR – Small-scale fishery based in rural communities using 5–8 m open-deck boats and stationary nets. Exclusively in Patos Lagoon estuary; also during shrimping season
6	ARU – Small-scale fishery using 5–8 m open-deck boats. Based in urban communities and using stationary nets. Exclusively in the Patos Lagoon estuary and during shrimping season
7	ASE – Small-scale fishery using small boats with fixed nets targeting shrimp in the Laguna Lagoon (SC) estuary. Based in urban communities
8	ASG – Small-scale fishery using various types of 9–14 m boats with gillnets mainly targeting croaker (corvina) in coastal waters (SC, RS, SP). Based in urban communities in Santa Catarina
9	AST – Small-scale fishery using 9–14 m boats with double-rigged pair trawls targeting shrimp in coastal waters of SC. Based in urban communities in Santa Catarina
10	SRG – Medium sized 13–20 m boats with 100–250 HP using gillnets targeting demersal fishes on the shelf off Rio Grande do Sul. Based in an urban community mostly in Rio Grande
11	SSG – Medium sized 9–14 m boats using gill nets on the inner shelf of Santa Catarina and northern Rio Grande do Sul. Based in an urban community in Paso de Torres
12	SSP – Medium sized purse-seining fishery using 14–18 m boats with 60–90 HP. Mainly fishing for sardines on the SC inner shelf. Based in southern Santa Catarina urban communities
13	IDC – Industrial otter trawl fishery using14–26 m boats with 115 to > 350 HP targeting demersal fishes and shrimp on the shelf at depths below 100 m along southern Brazil
14	IGC – Industrial bottom gill-net fishery using 18–26 m boats with 100 to > 350 HP targeting demersal fishes on the shelf and upper slope along southern Brazil
15	IGS – Industrial surface gillnet fishery using 18–24m medium size boats with 200–360 HP targeting croakers, bluefish, weakfish and large pelagic sharks on the shelf and upper slope along southeastern and southern Brazil
16	ILO – Industrial surface long-line and hand-line fishery using 20–33 m large boats with 250–450 HP targeting tunas and swordfishes from the outer shelf to oceanic waters along southeastern and southern Brazil
17	ILS – Industrial bottom long-line and hand-line fishery using 18–26 m large boats with 260–350 HP on the upper slope along southeastern and southern Brazil
18	IOC – Industrial otter trawl fishery using 20–32 m boats with up to 350 HP targeting demersal fishes, mainly shelf sciaenids and at depths below 100 m along southern Brazil
19	IOS – Industrial otter trawl fishery using 22–35 m large boats with > 350 HP targeting mainly demersal fishes such as hakes and monkfish on the upper slope along southern Brazil
20	IPC – Industrial pair trawl fishery using 20–32m boats with up to 350 HP targeting demersal fishes, mainly shelf sciaenids and at depths below 100 m along RS, SC, PR and SP
21	IPL – Industrial pole-and-live-bait fishery using 20–35 m boats with > 350 HP targeting skipjack and yellowfin on the outer shelf and upper slope from RJ to RS
22	IPS – Industrial purse-seining fishery using 18–26 m boats with 260–350 HP and skiff boats on the shelf along southeastern and southern Brazil
23	FCS – Leased foreign pot vessel fishery using 28–63 m boats with 350–2000 HP targeting red crabs on the upper slope along southern Brazil
24	FGS – Leased 26–40 m foreign vessels with 500–1200 HP. Bottom gillnet fishing on the outer shelf and upper slope along southeastern and southern Brazil. Targeted monkfish with a large bycatch of other fishes and crabs. Fished only in 2001 and 2002
25	FLS – Leased 27–40 m foreign vessels with 800–1100 HP. Bottom long-line fishing on the upper slope along southern Brazil. Targeted wreckfish, groupers, tilefish and other large bony fishes. Fished only in 2001 and 2002
26	FOS – Leased foreign vessels up to 60 m and 2200 HP. Trawl fishery in the upper slope along southern and southeastern Brazil targeting hakes, monkfish, silver john dory and squid

east and southern fisheries, eight of these attributes were not considered; the remaining 49 attributes were distributed among five evaluation fields or dimensions: technological, economic, ecological, social and management (Table 2). These attributes were chosen based on their relevance as descriptors of the evaluation fields, availability of information, discrimination power among FPS, and the possible relationship to sustainability. Selection and categorization of the attributes were established in common with other regional groups in a 2004 national workshop on the RECOS project. For each attribute, a scale with three to five levels was established. These levels were designed based on interviews with the various stakeholders, such as small-scale fishers, industrial fishing skippers and crew members, ship owners, buyers and other participants in the fish production chain, and recorded in detailed questionnaires in 2003 and 2004. An important part of the research work, these interviews provided much insight into the dynamics of artisanal and industrial fisheries.

Three attributes from each evaluation field were selected to form the sixth evaluation field, entitled 'sustainability' (Table 2), having been adjudged as closely related to the long-term viability of the FPS. A squared Euclidean distance matrix was constructed for each evaluation field and the attributed scores were normalized using Z-values. Goodness-of-fit assessment stress values < 0.25 were considered as acceptable (Clarke and Warwick, 1994).

Considering attributes such as explanatory variables and the values of each FPS in the two first dimensions of the MDS, a canonical correlation analysis (CCA) was used to evaluate which dimensions were common within the FPS and how much variance was shared. Correlations between attributes and the first two axes of the MDS plot (Table 2) were assessed. Correlations over 0.6 were selected to show how the original attributes related to the derived MDS ordinations. In the sustainability evaluation field, two hypothetical points of reference were introduced representing ideal 'good' and 'bad' FPS based on the selected attributes.

Results

Social dimension

Three groups of FPS were identified with respect to the social dimension: the industrial, the small scale and the foreign fishing systems.

Table 2
Ecological, social, technological, economic and management attributes used to characterize various fishing production systems

Dimension	Attribute	Axis 1	Axis 2
Ecological	Environmental vulnerability (1) low to (5) high	−0.76	−0.50
	Primary productivity (1) oligotrophic to (3) eutrophic	−0.74	0.38
	*Environmental degradation (1) high to (3) none	0.59	−0.58
	Environmental changes (1) worsening to (3) recovering	0.40	−0.76
	Habitat extension changes (1) rapidly decreasing to (4) expanding	−0.31	0.86
	Number of target species (1) 1 sp. (2) 2–10 spp. (3) >10 spp.	0.34	−0.41
	Target species changes (1) yes (2) % catch changes (3) no changes	0.17	−0.08
	Life cycle length (1) 1–2 yrs, (2) 5–10 yrs, (3) >10 yrs	0.72	0.43
	Vulnerability at reproduction (1) high to (3) any	0.50	0.33
	Vulnerability at rearing (1) high to (3) any	−0.72	−0.47
	*Discard levels (1) high to (3) any	0.58	0.36
	*Exploitation level (1) overexploited to (4) underexploited	−0.73	−0.37
	Changes in fish size (1) strong, (2) slow, (3) none	0.73	0.44
	Gear effects (1) low to (3) high	−0.49	0.04
Social	Professional indicators (1) poor to (5) excellent	−0.82	0.01
	Working relationships (1) familiar (2) partnership (3) wedge guarantee	0.79	0.07
	*Instruction level (1) low to (3) high	−0.29	0.41
	Residence distance from fishing grounds (1) local to (5) foreign country	−0.69	−0.47
	Health assistance (1) poor to (6) excellent	−0.69	−0.61
	*Social organization (1) nonexistent to (5) strong	−0.94	0.18
	Public transport availability (1) only by water, (2) bad roads, (3) good	−0.67	0.38
	Place of residence (1) isolated village to (4) large town	−0.78	−0.47
	Residence quality (1) poor to (5) excellent	−0.44	0.32
	*Changes in the number of fishers	0.24	0.73
Technological	*Gear selectivity (1) low to (5) high	0.12	0.51
	Trip length in days (1) 0–1; (2) 2–5; (3) 6–15; (4) 16–30; (5) >30	−0.92	−0.09
	Fish processing and conservation (1) none; (2) little; (3)high	−0.90	−0.16
	Positioning and fish finding technology (1) none to (4) high	−0.88	0.33
	*Fishing power changes (1) decreasing (2) unchanged (3) increasing	0.63	0.41
	Power source (1) any (2) rowing (3) sail (4) <20 HP (5) 20–200 HP (6) >200 HP engine power	−0.92	0.10
	Communication means (1) none (2) short range (3) long range	−0.90	0.25
	*Effort changes (1) decreasing (2) stable (3) increasing	0.05	0.72
Economical	Fish value per kg (1) <2$R, (2) 3–6$R, (3) 7–15$R, (4) 16–30$R, (5) >30$R	−0.43	−0.33
	Annual production (mt) (1) <0.1, (2) 0.1–1, (3) 1–10, (4) 10–100, (5) >100	−0.85	0.26
	Added value (1) low to (5) high	−0.87	0.33
	*Comparative per capita earnings (1) lower to (3) higher	−0.92	−0.02
	Other earning sources (1) never (2) occasional (3) frequent	0.59	−0.63
	Gear costs (1) low to (5) high	0.92	−0.18
	Changes in value (1) low to (4) high	0.42	−0.09
	Final consumers (1) local, (2) regional, (3) national, (4) international	−0.74	0.19
	*Direct and indirect subsides (1) many to (3) none	0.95	0.18
	*Middlemen dependence (1) any to (4) high	0.85	0.37
Management	Access restrictions (1) any, (2) inefficient, (3) efficient	0.18	−0.53
	Reference points (1) any, (2) some, (3) many	−0.52	−0.26
	*Traditional management (1) any, (2) some, (3) many	−0.73	−0.17
	Institutional management measures (1) any, (2) some, (3) many	−0.54	−0.39
	Stakeholder participation (1) any, (2) some, (3) all	−0.77	−0.11
	*Conflict intensity (1) confrontation (2) high, (3) low, (4) none	0.66	0.36
	Landings statistics (1) none,(2) partial,(3) total,(4) trustable, (5) available	0.09	−0.55
	*Enforcement (1) non existent (2) non efficient (3) efficient	−0.76	0.20

Two columns include scores of the first two axes in a Canonical Correlation Analysis.
*Selected attributes associated with sustainability.

The social dimension analysis was based on six attributes that showed correlations over 0.6. Four attributes were correlated to the 1st axis: working relationships, professional indicators, social organizations and place of residence. Two attributes were correlated to the 2nd axis: health benefits and new entrants to the fishery activity (Table 2).

The MDS plot in Fig. 1a in the upper right corner shows that the industrial FPS in SC and RS forms a relatively homogeneous group. Fishers in the industrial fishing systems are formally organized in unions, receive a minimum basic wage, and live in urban areas with access to schools, transportation and other basic services. Small and middle-scale FPS are in the center of the plot, but their working relationships segregate to the left with small-scale FPS (fishers working in family partnerships) and to the right with middle-scale FPS (fishers working in informal relationships). Small-scale FPS from the Patos Lagoon are in the lower left corner of the plot, showing the worst social indicators. Leased foreign industrial FPS appears to be very homogenous, with foreign fishers living in towns in areas with good infrastructure and enjoying good social security benefits.

Changes in the number of fishers were observed in a considerable number of FPS. The largest decrease of new entrants to the fishery was reported among rural, occasional Patos Lagoon fishers, pair bottom trawling and deep-water long-line fishing. The number of fishers increased for industrial purse seining, surface long-line, double rig trawling, and middle-scale gill netting as well as small-scale FPS in SC and the Patos Lagoon estuary.

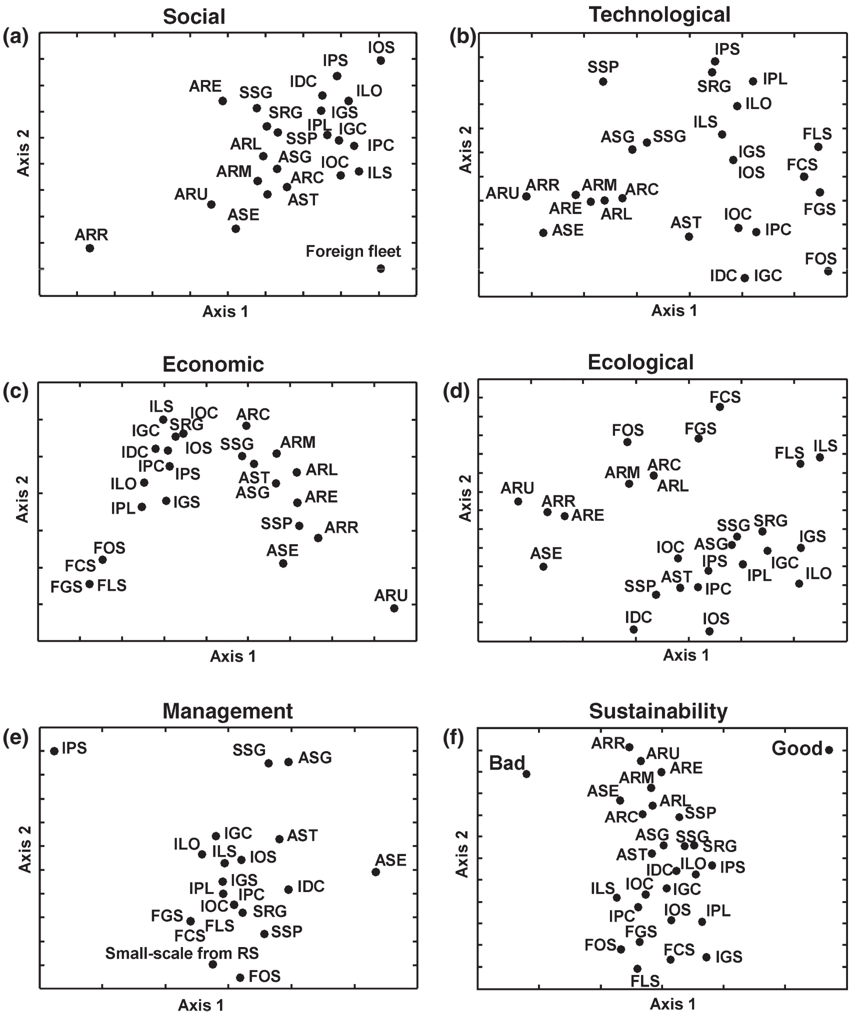

Fig. 1. Fishing production systems in southern Brazil according to attributes of social (a), technological (b), economic (c), ecological (d), management (e) and sustainability (f) evaluation fields using a multidimensional scale technique

Technological dimension

Overall, the MDS plot shows a gradient along the 1st axis from low to intense use of technology in small-scale FPS on the left to intense use on the right with both industrial and leased foreign FPS. There is a clear association of change in effort in the 2nd axis. However, the associations of other attributes are less clear. The leased foreign FPS form a relatively homogenous group that has an increased fishing effort and employs more complex technology such as GPS, radar, sonar and echo-sounders in trips of medium to long duration (Fig. 1b). Bottom trawlers and long-liners from SC, industrial FPS from SC and RS, and small-scale FPS from RS all form a group characterized by use of GPS and echo-sounders. Small-scale FPS from RS and SC usually use few technological devices such as GPS, as their trips are generally short and fish processing is non-existent or rudimentary.

Economic dimension

Overall, the MDS plot shows the foreign FPS in the lower left corner, the national industrial FPS in the middle top, and the small and middle-scale FPS in the mid- to lower right (Fig. 1c). The economic dimension analysis was based on seven attributes that had correlations over 0.6 with the 1st axis, but none of the attributes was correlated with the 2nd axis. The foreign FPS are strongly grouped and show the best economic indicators; all are capital intensive, operate with large vessels and have onboard processing and freezing capacity; and the target species have high export market value and generate the highest per capita income. The economic attributes appear to show a strong correlation with the scale of production, investment, infrastructure and access to markets of the developed countries. However, the 'better' economic performances of foreign FPS are not necessarily encouraging, as they have a well-deserved reputation for over-fishing important Brazilian stocks such as monkfish and deep sea crabs. The national industrial FPS was also well grouped, with pole-and-live-bait and bottom long-line fishing showing a slightly better performance. Largest heterogeneity was among small-scale and middle-scale FPS, which showed the worst economic indices.

Ecological dimension

Overall, the ecological attributes appear to show a gradient of FPS ranging from productive but degraded environments with fast-growing species to less productive but more stable environments with slow-growing fish species.

The ecological dimension analysis was based on eight attributes that showed correlations over 0.6. Six of the attributes were correlated with the 1st axis: environmental and pre-recruitment vulnerability, primary productivity, life-cycle length of the target species, exploitation level and changes in fish sizes. Two attributes correlated with the 2nd axis: environmental changes and habitat extension (Table 2). Notable is that six of the attributes correlating the most ($r > 0.8$) with the first two axes are associated with oceanic waters, a fact that decreases environmental vulnerability and environmental change, pre-recruitment vulnerability and partial vulnerability at reproduction.

The estuarine small-scale FPS from SC and RS are grouped on the left of the MDS plot (Fig. 1d). All use passive fishing gear in high productivity estuarine environments where juveniles are reared and most target species are fast-growing, such as white croakers and mullets, or short-lived, such as shrimps. Three small-scale FPS are grouped in the center of the plot; these operate in estuaries and fresh (ARL) or coastal waters (ARM, ARC), the largest and less impacted environments. At the top of the plot is a group of foreign FPS that fish for long-lived species in waters of low productivity and with a low environmental vulnerability. The foreign and national bottom long-liners are grouped in the upper right corner, as these FPS have both collapsed. Most of the industrial and middle-scale FPS are grouped in the lower right section, as they fish coastal and shelf waters for fish species with medium- to long-life cycles in productive environments in which juveniles are vulnerable, particularly to intense trawling.

Management dimension

The analysis of this dimension showed FPS with some degree of management and others with no management at all. This analysis was based on eight attributes that had correlations over 0.6. Four attributes had high correlations with the 1st axis (Table 2).

Most FPS were grouped near the center of the MDS plot (Fig. 1e), as most of them are industrial FPS that restrict access in various ways and have relatively accurate landing statistics, although few have formal, established procedures for assessment of management measures. Foreign fleets and other industrial FPS, such as bottom and industrial gillnet, pole-and-live-bait, pair trawl and bottom long-line, have practically the same scores; they differ only in the level of available statistics. Landing statistics for the foreign fleets are collected by onboard observers and thus are more precise than those for the other industrial FPS.

Other FPS represent atypical situations. Small-scale shrimp FPS in SC (ASE) at the center right of the MDS plot are characterized by an open-access regime with unreliable landing statistics and few conflicts. Purse seine FPS (IPS) are in the upper left corner. Reference points were determined by scientific information and official measures, which limit access to the fishery. Small-scale FPS in RS are at the bottom of the MDS plot and differ from all other systems in that they follow traditional management rules, have a high stakeholder participation, and a well-established co-management institution.

Sustainability dimension

The FPS forms a relatively homogeneous group in the 1st axis without a clear gradient and is equidistant from the ideal 'good' and 'bad' systems (Fig. 1f), showing that there are no clearly sustainable or unsustainable fisheries in southern Brazil. For this dimension a total of nine attributes had correlations over 0.6. Four attributes were correlated with the 1st axis (changes in the number of fishers, environmental degradation, gear selectivity, and effort); five attributes were correlated with the 2nd axis (social organization, fishing power changes, comparative per capita earnings, direct or indirect subsidies and traditional management). However, the FPS were more heterogeneous with respect to the 2nd axis. Four foreign FPS are at the bottom of the plot, followed upwards along the 2nd axis by bottom trawler industrial FPS, long-liners, gillnetters, and purse-seiner FPS. The small- and middle-scale FPS are at the top of the plot.

The FPS closest to 'bad' sustainability situations are foreign and bottom trawlers. This was true even though coastal gillnetting in southern Brazil endangers species of coastal porpoises (*Pontoporia blainvillei*) and sharks (Secchi et al., 1997; Vooren and Klippel, 2005). FPS closest to 'good' situations of sustainability are industrial seining, middle-scale surface gillnetters, and pole-and-live-baiters.

To compare the FPS in terms of sustainability in more detail, the means of the attributes in each dimension were calculated as percentages of the scores of the ideally 'good' fishery and plotted as kite diagrams (Fig. 2). The best and

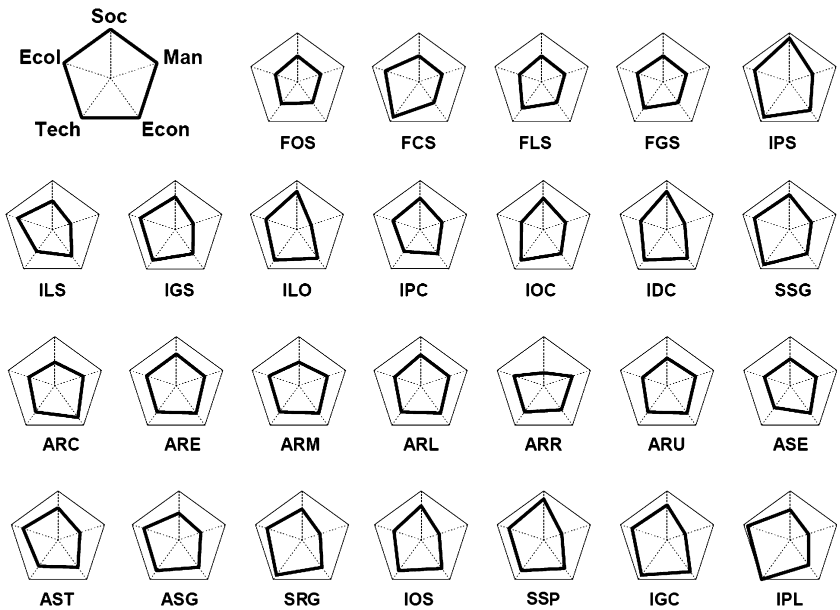

Fig. 2. Kite diagrams for 26 fishing systems. Each diagram combines a standardized measure of each of five analyzed dimensions representing a picture of overall balance between dimensions. Fishing system acronyms given in Table 1

worst sustainability indices were for technological and management dimensions, respectively. Only four FPS (FOS, SSP, ARL and ARE) showed some equilibrium among all five dimensions. All 22 other FPS were strongly asymmetric towards one or more dimensions, notably SSG, SRG, ARU, IPL, and IGC.

Discussion

Fisheries sustainability

The sustainability analysis did not showed a clear gradient among the different FPS of southern Brazil, as most fishing systems were equidistant from the ideal 'good' and 'bad' points. In the fields of social, technological and economic evaluation dimensions, values showed a clear separation in the four categories of small-scale, middle scale, industrial and foreign fleet fishing systems.

The ordination of FPS in the ecological dimension follows the environmental axis of estuary – shelf – slope. The worst indicators are those regarding FPS fishing in estuaries and coastal waters, which have production and environmental vulnerability and are therefore more vulnerable to fishing and other anthropogenic impacts. By contrast, the best indicators are related to reproductive and nursery grounds in offshore waters where impacts are minimal, ecological vulnerability is low, and productivity is lower or moderate.

The patterns regarding management are less clear; no environmental or fishery categories gradient were observed. The best indicators are those of the FPS with scientifically established reference points and with efficient, enforced access rules such as for skipjack tuna and other tunas. On the other hand, less specific FPS such as bottom trawl and gillnet fisheries, which comprise a large amount of the marine and estuarine fish catches in southern Brazil, perform poorly. As expected, the pattern of the sustainability analysis recalls the social, technological and economic gradients. Despite the fact that all FPS showed intermediate levels of sustainability, there was a clear difference among the four groups with respect to the social, technological and economic gradients. On one side is the foreign fleet with the most 'sustainable' social, economic and ecological indicators; on the other side are the estuarine small-scale fisheries where good indicators of sustainability are related to traditional management, few subsidies and lower fishing intensity.

RAPFISH methodology

We believe that our use of the RAPFISH methodology to identify, compare, and assess the sustainability of fisheries in southern Brazil fell short of producing clear patterns, and of identifying clearly unsustainable fisheries. This occurred because the RAPFISH methodology gives equal weight to all five analyzed dimensions. For example, FPS directed to one or few species in southern Brazil, such as those aimed at sardine, skipjack tuna and other tunas, tended to have better indicators of sustainability than less specific FPS such as bottom trawl and gillnet fisheries, which comprise a large segment of the marine and estuarine fish catches in southern Brazil. However, sustainability is known to be incompatible with high fishing effort, regardless of economic, social, and technological considerations, as is currently the case in most southern Brazil fisheries (Haimovici et al., 2006b). In the analysis of our systems we observed that larger indices of sustainability in one dimension were neutralized by poor performances in other dimensions (Fig. 2). For example, the *Forum da Lagoa dos Patos* is a NGO participatory management institution in which small-scale fishers and their representatives in the estuary and adjacent marine areas meet regularly with managers, authorities and other stakeholders to discuss and propose management measures (Reis and D'Incao, 2000). For example, the *Forum* has implemented several traditional fishing measures such as a fishing calendar and a system of space allocation for fishers to install their nets for targeting shrimp and other resources. However, in spite of this participatory arrangement, the *Forum* is not able to address over-exploitation effectively. Another example is the seine fishery of *Sardinella brasiliensis,* a widely studied and regulated sardine species that has not recovered to its previously abundant levels. As a small pelagic fish it is subject to recruitment variability related to oceanographic variability; however, overfishing is also part of the problem (Cergole, 1995). On the other hand, the pole-and-live-bait fishery for skipjack tuna has remained rather stable over the past 20 years (Andrade, 2005). The increase in landings of this fishery has been constrained by the limited availability of young sardines, which are the preferred live bait but also a source of a bitter and unresolved conflict with sardine purse-seine skippers. Brazilian legislation regulates the skipjack tuna by forbidding catches between latitudes 18ºS and 35ºS and also by obliging fishing boats to catch their own bait. These regulations have been critical to moderating the fishing effort and, thus far, have prevented overfishing. Nonetheless, this apparent sustainability is fragile, as pressure by the fishing sector could increase the number of boats or introduce changes to the current legislation.

This attempt to relate attributes of FPS to sustainability by using RAPFISH methodology missed the detection of clearly unsustainable FPS, such as foreign fleets and industrial trawling fishery systems. We believe that problems of biological, ecological and status of exploitation were not given enough emphasis in the analyses. As shown above, sustainability is incompatible with high fishing effort, regardless of economic, social, and technological considerations, which appears to be the case in most fishery systems in southern Brazil (Haimovici et al., 2006b).

In the 'Code of Conduct for Responsible Fishery' (FAO, 1995), fishery sustainability is seen as a '*desideratum*' that can only be reached through a multidimensional approach in which the ecological, social, technological, economic and governance dimensions are equally considered. Managers also suffer social pressures and thereby give equal value to all dimensions of the fishery; as a result they promote measures that in turn promote resource overexploitation. However, based on analyses of the FPS in southern Brazil we conclude that the biological and ecological attributes of fisheries constrain management options in relation to the other dimensions. These biological and ecological dimensions are of paramount importance because their attributes control biomass production.

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